Calibrated Peer Review Assignments in Science Courses

Are They Designed to Promote Critical Thinking and Writing Skills?

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Calibrated Peer Review (CPR), an online program that purportedly helps students develop as writers and critical thinkers, is being increasingly used by science educators. CPR is an enticing tool since it does not require instructors to grade student writing, and instructors can adopt assignments directly from a library. To determine the extent to which CPR is being used to foster the development of critical thinking and writing skills, we analyzed a sample from the CPR assignment library. We found that approximately two-thirds of assignments were designed to engage students in some type of critical thinking, but less than one-third were designed to promote higher-order writing skills. We recommend that the current library be used with caution, a CPR user manual be written (with detailed instructions for creating high-quality writing assignments), and that a new CPR library be created to include only assignments that have been reviewed by experts in critical thinking or writing pedagogy.

Science educators are increasingly being encouraged to include writing assignments in their undergraduate courses to promote critical thinking and writing abilities (Carlson 1995; NRC 2003). To cope with the significant challenges associated with large classes, grading burdens, and a lack of teacher expertise in creating and evaluating writing assignments (Hobson and Schafermeyer 1994), instructors are frequently turning to education technology for help, and many are choosing Calibrated Peer Review (CPR, available at *http://cpr.molsci.ucla.edu*). CPR has been adopted by over 800 institutions and used by more than 120,000 students (Russell 2005). This web-based program is attractive because it enables frequent writing assignments with minimal involvement and no grading of student writing by instructors. It is not surprising that science educators find this package appealing, especially considering that CPR is supported by both the National Science Foundation and the Howard Hughes Medical Institute and that it is free (Stokstad 2001).

CPR guides students through two distinct phases for every assignment (Table 1). In what we call the *writing phase*, students are asked to compose their papers and then upload them to the CPR server. In the *reviewing phase*, students first read and evaluate three responses to the assignment of varying quality (called "calibration essays") using a rubric designed for that assignment. Once students have completed their assessment of these calibration essays, they use the rubric to anonymously review and grade three of their classmates' papers and, finally, their own.

CPR has been promoted as a powerful tool for helping students improve critical thinking and writing skills (Carlson and Berry 2003; Carlson, Berry, and Voltmer 2005; Donovan 2003; Robinson 2001). Such claims imply that CPR has a built-in pedagogy and that students will benefit simply by using this technology. CPR is, however, only a framework for delivering and managing assignments; the pedagogy comes primarily from the assignments, and these are typically developed by individual instructors for their particular courses to achieve specific learning outcomes. It is critical to recognize that what students learn from a writing assignment is strongly dependent on how the assignment is designed and articulated, since this can have a substantial effect on how students respond to the task (see, for example, Driskill et al. 1998; Greene 1994; Penrose 1993). Students are unlikely to engage higher-order cognitive or writing skills unless assignments are designed to encourage such work. Furthermore, unless assignments *require* such engagement, many students will take shortcuts that undermine teachers' learning objectives for those assignments (Nelson 1990, 1992).

Assignment design is of particular concern for CPR because it is the single most challenging and time-consuming aspect of implementing the system (Table 1, Step 1). Not only must instructors develop the assignment itself, they must compose three responses of varying quality for each assignment, since these are the benchmarks for the calibration of student work. Hence, instructors are encouraged to adopt or adapt assignments directly from the CPR Server Assignment Library (Margerum et

al. 2007; Russell 2004), an unfiltered repository of assignments contributed by educators representing a wide range of institutions and disciplines.

There is some evidence suggesting that well-written CPR assignments can help students master course content (Furman and Robinson 2003; Gerdeman, Russell, and Worden 2007; Kim, Wise, and Hillsley 2005; Margerum et al. 2007; McCarty et al. 2005; Pelaez 2002; Prichard 2005) and that CPR can be as effective as some other methods of teaching writing (McCarty et al. 2005; Plutsky and Wilson 2004). However, all previous studies of CPR are limited to evaluations of specific assignments within unique courses and so are unable to tell us anything about the pedagogical value of CPR assignments in general. With an increasing number of instructors relying on the library, we feel that there is a need for a critical examination of this resource. Therefore, the goal of this study is to determine how often CPR assignments are designed to foster the development of critical thinking and writing skills. To do this, we use the library as a convenience sample of CPR assignments.

Methods

Our sample was drawn from assignments contributed to the CPR assignment library between 2000 and 2006. Given our mutual interest in science education, and because the majority of CPR assignments are

TABLE 1

Overview of a CPR assignment.

Step 1	Step 2	
What educators do	**What CPR does**	**What students do**
Option 1	***The writing phase***	
E1. Determine the desired learning outcomes of the assignment	C1. Implements the assignment at the designated time	S1. Read the assignment and reference materials S2. Write essays
E2. Select topic and reference material	***The reviewing phase I: Calibrations***	
E3. Write the assignment	C2. Provides students with three calibration essays (in random order)	S3. Review each essay, using rubric (see E5) and assign a holistic score (see E7)
E4. Write three sample responses to the assignment (i.e., the "calibration essays"), including a *high-quality* sample (that meets all learning objectives), and *mid-* and *low-quality* samples	C3. Evaluates students' ability to effectively review essays (see E6)	S4. Review feedback of performance (see C4)
E5. Write a set of guiding questions (i.e., rubric) that focuses attention on key aspects of the writing, thus teaching students how to evaluate the essays	C4. Provides feedback (pass/fail based on standards set by instructor, see E9)	S5. If calibration stage successfully completed, go to peer review; otherwise repeat one or more calibrations
E6. Evaluate the calibration essays using the rubric, thus setting the evaluation standards	C5. Requires students to repeat calibration stage if not successfully completed	
E7. Give each calibration essay a holistic score (from 1–10). CPR does not weight the rubric questions to calculate an essay's grade; the grade is based entirely on this holistic rating.	C6. Calculates a Reader Competency Index (RCI) for each student. RCI is a score from 1–6 based on demonstrated competencies using rubric (see E6) and scoring essays (see E7)	
E8. Upload assignments into CPR	***The reviewing phase II: Peer Review***	
E9. Select a grading template within CPR (low, moderate, or high difficulty), and determine how much each item will be weighted in determining students' CPR grade (see C8)	C7. Randomly assigns three anonymous peer essays to review	S6. Anonymously review three peers' essays using rubric S7. Score each essay
Option 2	***The reviewing phase III: Self-Assessment***	
E1a. Select an existing CPR assignment from the library	C8. Calculates students' CPR grade based on • essay quality (i.e., average of three reviewers' scores, weighted by RCI), • calibration (see C4), • peer reviews, and • self-assessment.	S8. Review their own essays using rubric S9. Score their own essays
E2a. Select a grading template within CPR (low, moderate, or high difficulty), and determine how much each item will be weighted in determining students' CPR grade (see C8)		

TABLE 2

Classification used to distinguish between lower-order cognitive skills (LC) and higher-order cognitive skills (HC), based on Bloom's taxonomy of educational objectives (Bloom 1984).

	Competence	Skills demonstrated
Lower-order cognitive skills (LC)	**Knowledge**	Observation and recollection of information Knowledge of dates, events, places, or major ideas Mastery of subject matter *Question cues:* list, define, tell, describe, identify, show, label, collect, examine, tabulate, quote, name, who, when, where
	Comprehension	Understanding of information Grasp of meaning Translation of knowledge into new context Interpretation of facts, comparison, contrast *Question cues:* summarize, describe, interpret, contrast, predict, associate, distinguish, estimate, differentiate, discuss, extend
Higher-order cognitive skills (HC)	**Application**	Use of information Use of methods, concepts, theories in new situations Solution of problems using required skills or knowledge *Questions cues:* apply, demonstrate, calculate, illustrate, show, solve, examine, modify, relate, change, classify, experiment, discover
	Analysis	Seeing of patterns Organization of parts Recognition of hidden meanings Identification of components *Question cues:* analyze, separate, order, explain, connect, classify, arrange, divide, compare, select, explain, infer
	Synthesis	Use of old ideas to create new ones Generalization from given facts Relation of knowledge from several areas Prediction, drawing of conclusions *Question cues:* combine, integrate, modify, rearrange, substitute, plan, create, design, invent, what if, compose, formulate, prepare, generalize, rewrite
	Evaluation	Comparison of and discrimination between ideas Assessment of value of theories, presentations Choices made based on reasoned argument Verification of value of evidence Recognition of subjectivity *Question cues:* assess, decide, rank, grade, test, measure, recommend, convince, select, judge, explain, discriminate, support, conclude, compare, summarize

created for STEM courses, we limited our assessment to science, engineering, and mathematics topics, resulting in 106 assignments contributed by 36 authors. Our initial survey of the library revealed that authors who contribute multiple assignments tend to duplicate significant portions of their previous assignments. To avoid overrepresenting the approach of a few authors, we randomly selected a single assignment from each author, resulting in a sample of 36 assignments. These assignments were designed primarily for undergraduates, but a few were for high school or graduate courses.

Because CPR makes different intellectual demands of students dur-

ing the writing and reviewing phases (Table 1, Step 2), we analyzed those parts of each assignment separately. In the writing phase, we examined 139 references to sources, 27 sets of student instructions, 205 guiding questions, and 33 prompts. In the reviewing phase, we examined 36 rubrics, consisting of 421 questions, which are provided to students when reviewing the calibration and peer essays.

To assess whether or not assignments required critical thinking skills, we looked for instructions or question cues that would indicate the level of abstract thinking the assignment required. We used Bloom's taxonomy (1984) as the basis of this part of our analysis. We defined "lower-order cognitive skills" (LC) as those required for knowledge and comprehension, and "higher-order cognitive skills" (HC) as those required for application, analysis, synthesis, and evaluation (Table 2). To assess whether or not assignments were designed to develop students' writing skills, we looked for instructions or question cues that directed students' attention to how they wrote their papers. We defined "lower-order writing skills" (LW) as those associated with proofreading, such as correct spelling, grammar, and punctuation. We defined "higher-order writing skills" (HW) as those skills needed to construct a coherent analysis or argument, such as organization, development of reasoning, use of evidence, appropriate use of sources, and attention to audience.

Both authors of this study independently evaluated each CPR assignment in the sample. In evaluating each assignment, we looked for explicit and implicit language that would indicate that students would be required to use specific cognitive or writing skills to write a strong paper. Each rater gave every assignment eight scores indicating the presence or absence of LC, HC, LW, and HW in the writing phase and in the reviewing phase. For example, if in the writing phase of an assignment students were asked to describe the life cycle of seedless, vascular plants, we would have assigned a score of "present" for LC because students were asked to recall and restate knowledge, both of which are lower-order cognitive skills. If the assignment also asked students to describe how they would determine whether or not an unknown plant is vascular, we would have assigned a score of "present" for HC since students would have needed to use information about vascular plants and apply that information to a novel situation, which is a higher-order cognitive skill. If the assignment asked students to proofread their essays for spelling errors, for example, then we would have assigned a score of "present" for LW since the instructions directed students' attention to lower-order writing skills. Finally, if the assignment asked students to use evidence from their reading to support their argument, then we would have assigned a score of "present" for HW since there were explicit instructions for students to address a higher-order writing skill. We analyzed the reviewing phase of each assignment similarly.

Prior to assessing the assignments in our sample, we underwent experiential training using the assessment criteria; we independently evaluated approximately 30 CPR assignments from the library that were not part of our sample. After we scored each assignment, we compared our evaluations and discussed any discrepancies until we agreed upon the most accurate rating. For the assessment of assignments in our sample, we independently evaluated two or three assignments, and then discussed our evaluations. We did not change our scores as a result of these discussions, but they helped us improve the accuracy of future evaluations.

We used two approaches to determine the level of inter-rater reliability. First, since the scores are categorical in nature, we computed the joint agreement between the two raters. To do this we calculated the number of times that each analyst gave the same rating for an item and divided this sum by the total number of ratings for that item. Second, we computed kappa coefficients to determine the statistical significance of these levels of agreement for each item assessed (Cohen 1960; Landis and Koch 1977).

Finally, since we were interested in revealing trends in assignment design, we calculated the mean proportion of assignments that require LC, HC, LW, and HW in the writing and reviewing phases, and calculated the 95% confidence intervals of these proportions using the methods of Cochran (1977).

Results

In the writing phase, we found that the mean proportion of assignments that required LC was 60.6% (95% CI 43.9, 77.2), and the mean proportion that required HC was 62.1% (95% CI 45.6, 78.7); only 6.1% (95% CI 0, 14.2) asked students to pay attention to LW, and 10.6% (95% CI 0.1, 21.1) required HW (Figure 1A). In the reviewing phase, 75% (95% CI 60.9, 89.1) of assignments required LC and 47.2% (95% CI 30.9, 63.5) required HC; 38.9% (95% CI 23.0, 54.8) of assignments required students to assess LW, and 27.8% (95% CI 13.1, 42.4) required them to assess HW (Figure 1B).

The levels of agreement between the two reviewers for the items analyzed ranged from 61% (kappa = 0.22) to 97% (kappa = 0.84) (Table 3).

Discussion

Because CPR is touted as being an effective tool for helping students improve their reasoning and writing capabilities, we sought to determine how frequently instructors were using it for these purposes. Our results suggest that CPR is being frequently used as a "writing to learn" (WTL) tool, where assignments use writing to help students think through key concepts or ideas presented in the course. While well-designed WTL assignments can help students both master course content and think critically about what they are learning, we are concerned that a large proportion of assignments appear to be focused

exclusively on LC (approximately 40% in the writing phase and >50% in the reviewing phase, Figure 1). It is not surprising that many lower-division science courses would prioritize content mastery, but we wonder if CPR is the most effective and efficient means of accomplishing this goal. Since having students review each others' papers is the defining feature of CPR, assignments that focus primarily on LC in the reviewing phase take very limited educational advantage of the system. Furthermore, current research on student learning indicates that students are most likely to develop deep and lasting knowledge not by simply restating information but by "constructing" knowledge for themselves (Fosnot 1996; Jaworski 1994; Prawat and Floden 1994; Steffe and Gale 1995). The constructivist approach to teaching and learning relies on the basic premise that an individual learner must make connections between their prior knowledge and new information. Students "build" their knowledge and skills through actively analyzing, applying, synthesizing, and evaluating new information.

Here is an example of how CPR assignments might be revised to engage students in higher-level reasoning. Currently, many CPR assignments embed answers directly into the grading rubrics (i.e., "Did the essay indicate that seedless, vascular plants have a dominant sporophyte?"), which requires students to simply identify the presence or absence of specific content or language in the essays. Although this practice may improve the accuracy and efficiency of peer grading, it strips the task of its higher-order cognitive activity. Instead, an instructor could embed such "answers" in the high-quality calibration essay and then ask more open-ended questions in the rubrics (i.e., "Did the essay accurately characterize seedless, vascular plants?"). This approach requires students to carefully read the calibration essays and then critically evaluate the accuracy of their peers' writing.

Our results also suggest that CPR is not often used effectively as a "learning to write" (LTW) tool. In the writing phase, we found that the vast majority of assignments give little or no attention to writing, while in the reviewing phase the dominant emphasis is on "error hunting" (i.e., looking for mistakes in spelling, punctuation, and grammar). Whereas CPR could be used to help students develop academic or professional writing skills, learn the writing conventions of a particular discipline, or understand how knowledge is produced and disseminated, we found that most writing instructions focused on proofreading or minor organizational features. Although students may need to pay more attention to proofreading, we are concerned that this activity was generally in lieu of, rather than in addition to, work on HW skills such as developing arguments, presenting evidence, or organizing ideas. While we did see a few examples of assignments containing strong writing pedagogies, our results do not support the notion that *typical* CPR assignments are likely to help students develop into stronger writers. We are concerned that well-intentioned instructors and administrators (and perhaps even accreditation reviewers) may mistakenly believe that certain courses are doing their part to support the development of students as writers merely on the grounds that these courses are employing CPR.

There are two important limitations of this study. First, since we limited our assessment to science, engineering, and mathematics topics, our finding are restricted to this component of the CPR library. Second, given the legalistic and practical difficulties associated with gathering and analyzing samples of student writing, our analysis is limited to assignments per se and, consequently, our results are necessarily based on inferences about how students would respond to these assignments.

Nevertheless, we have no reason to believe that these limitations bias our results in favor of the trends we describe. To the contrary, we believe our analysis sets a very low threshold for what we categorize as "high-level" work, since to get a ranking as HC or HW an assignment need only have exhibited a single "high-level" feature. For example, an assignment that only asked students to consider how a paper was organized would have been ranked as HW, regardless of how well the assignment was designed overall. Our results, therefore, likely give an optimistic view of CPR assignments.

TABLE 3

The levels of agreement between the two analysts for items in the prompts (n = 33) and the rubrics (n = 36). Levels of agreement indicated by Landis and Koch (1977).

	Item	Joint agreement	Kappa coefficient	95% confidence interval	Level of agreement
Analysis of prompts	LC	76%	0.50	0.21, 0.79	Moderate
	HC	79%	0.62	0.35, 0.89	Substantial
	LW	94%	0.48	-0.12, 1.00	Moderate
	HW	97%	0.84	0.54, 1.00	Almost perfect
Analysis of reviewing phase	LC	89%	0.72	0.47, 0.98	Substantial
	HC	61%	0.22	-0.10, 0.54	Fair
	LW	89%	0.77	0.56, 0.98	Substantial
	HW	78%	0.43	0.11, 0.74	Moderate

Toward better use of CPR

Because our analysis suggests that actual CPR use may not match expectations, we conclude with three recommendations. First, instructors must not assume that science, engineering, and mathematics assignments in the CPR library contain built-in pedagogies that will improve their students' ability to write and think critically. Many educators appear to use the CPR assignment library with the belief that effective pedagogies for achieving WTL and LTW goals have already been developed and can be put into practice merely by drawing on the available assignments. Our results suggest that this is not necessarily the case. In fact, we are concerned that the library may be propagating underdeveloped and, in some cases, counterproductive pedagogies.

Second, we recommend that a CPR user manual be created, containing detailed instructions for writing assignments that are designed to achieve specific WTL and LTW goals. This manual could include, for example, assignment templates and links to sample assignments that have been peer reviewed for content and pedagogical approach. We recommend that this manual be created by a blue-ribbon committee representing a broad range of users, developers, and teaching scholars.

Lastly, we strongly recommend that the CPR Server Assignment Library should only contain peer-reviewed assignments that are categorized according to the cognitive and writing skills they actually promote (for example, LC, HC, LW, and HW).

We are optimistic that CPR can be used more effectively, based in part on assignment-specific CPR research and the theoretical pedagogical value of peer review. Nevertheless, we must be careful that we do not allow technology to become a substitute for effective pedagogy.

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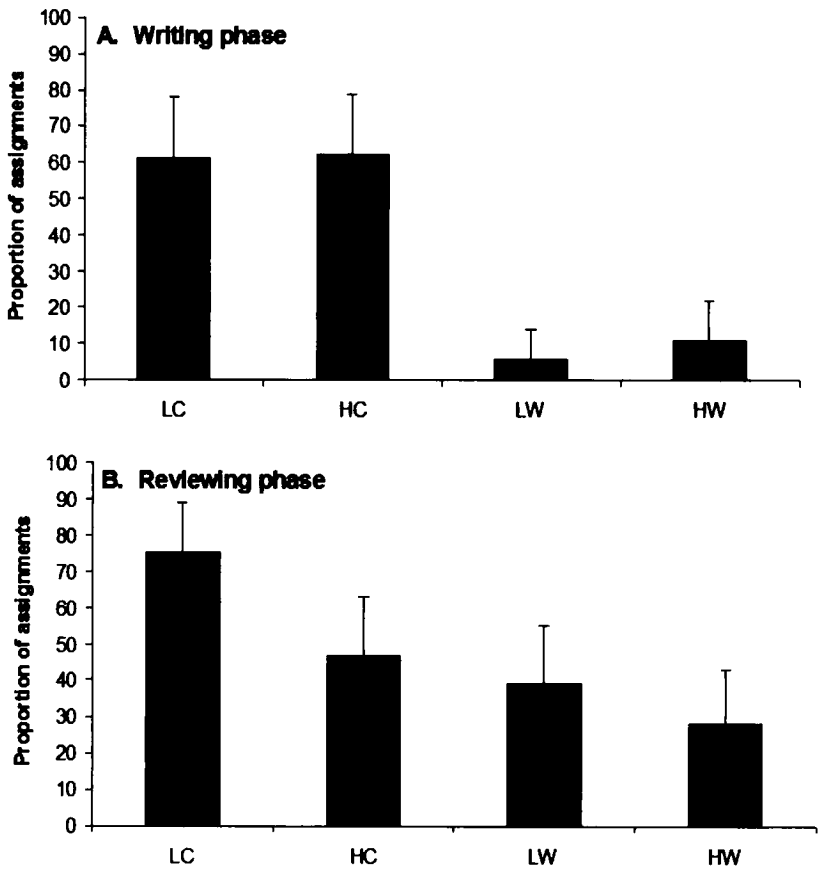
FIGURE 1

Mean proportion of CPR assignments that require students to use lower-order cognitive skills (LC), higher-order cognitive skills (HC), lower-order writing skills (LW), and higher-order writing skills (HW) in (A) writing phase and (B) reviewing phase of CPR. Categories are not mutually exclusive. Error bars represent the 95% confidence interval for the mean.



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